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## A HIGH RESOLUTION ULTRAVIOLET SHUTTLE GLOW SPECTROGRAPH

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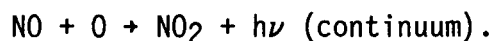
## ABSTRACT

The High Resolution Shuttle Glow Spectrograph-B (HRSGB-B) is a small payload being developed by the Naval Research Laboratory. It is intended for study of shuttle surface glow in the 180-400 nm near- and middle-ultraviolet wavelength range, with a spectral resolution of 0.2 nm. It will search for, among other possible features, the band systems of excited NO which result from surface-catalyzed combination of N and O. It may also detect O<sub>2</sub> Hertzberg bands and N<sub>2</sub> Vegard-Kaplan bands resulting from surface recombination. This wavelength range also includes possible N<sub>2</sub><sup>+</sup> and OH emissions. The HRSGB-B will be housed in a Get Away Special canister, mounted in the shuttle orbiter payload bay, and will observe the glow on the tail of the orbiter.

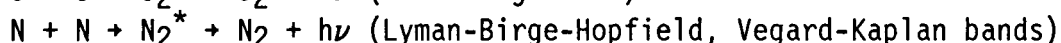
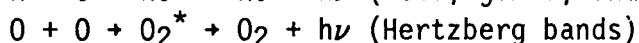
## INTRODUCTION AND BACKGROUND

Shuttle glow was first observed in the visible spectral range by astronauts on the STS-3 mission in 1982 (see Refs. 1 and 2). However, probably similar phenomena have also been observed by instruments on unmanned satellites<sup>3-5</sup>. The glow is observed only on surfaces of the shuttle orbiter (or other satellite vehicle) which face the direction of motion (ram). The glow intensity is observed to increase rapidly with increasing atmospheric density<sup>2,6</sup>. There have been several imaging and spectrographic studies of the visible shuttle glow<sup>6-8</sup>, but only limited observations of shuttle glow in the ultraviolet and infrared wavelength ranges.

The leading contenders among reaction mechanisms proposed to explain the glow are various recombination processes, involving reactive gases in the upper atmosphere such as O, N, and NO<sup>7,9-11</sup>. For example, the visible glow is thought to be largely due to the reaction



Other possible recombination reactions which produce molecules in excited states, which can then subsequently radiatively de-excite (producing radiation in the ultraviolet), include:



The ramming surface facilitates these reactions by compressing the gas, providing translational energy to the reacting atoms or molecules (by virtue of the 8 km/sec orbital velocity), and by providing temporary storage sites (on the solid surface) for reactive species.

Shuttle glow was imaged in the 180-200 nm far-UV wavelength range, for the first time, with NRL's Far Ultraviolet Cameras experiment during the STS-39 mission<sup>12</sup> (see Fig. 1). It is thought, but not proven, that the glow in this wavelength range is due to nitric oxide (NO)  $\delta$ -band emissions, produced by  $N + O$  recombination. If so, there should be equal or stronger NO band emissions in the 200-400 nm wavelength range. NO and  $NO^+$  emissions were observed in the infrared by the SKIRT experiment, also on the STS-39 mission<sup>13</sup>.

Emissions due to  $N_2$  and/or  $N_2^+$  may also be present in the UV below 400 nm. Water vapor outgassing may give rise to the OH resonance emission near 310 nm. However, there have so far been no spectrographic observations in the 180-200 nm range imaged by the Far UV Cameras, and neither imaging nor spectrographic measurements of shuttle glow (with positive detections) in the 200-400 nm range. Therefore, there is a need for follow-on spectrographic measurements in the ultraviolet wavelength range below 400 nm to identify, and measure the intensities of, the spectral emission features in this wavelength range.

## OBJECTIVES

The scientific objectives of HRSGB-B are to identify the chemical species and reactions which are responsible for producing shuttle glow in the 180-400 nm wavelength range. This requires the identification, and spectral intensity measurements of, emission features in this wavelength range with moderately high spectral resolution and high diffuse-source sensitivity. In addition, measurements of glow intensity vs. distance from the hard surface producing the glow (by ramming the ambient atmosphere) are required, particularly for determinations of the responsible reaction kinetics. These measurements will be compared with similar measurements of the visible glow. The UV measurements may also aid in understanding the surface glow observed at longer wavelengths, and in predicting intensities to be expected at shorter wavelengths in the far-UV.

## INSTRUMENTATION

The HRSGB-B scientific instrument is a high resolution imaging spectrograph, incorporating a UV-sensitive image intensifier, whose data are recorded as film images. The instrument is mounted in a Get Away Special canister, with the view direction toward the tail of the shuttle orbiter (see Fig. 2). During the flight mission, the glow on the surface of the orbiter is observed when either the payload bay or the wing on the side where the GAS canister is mounted is facing the velocity vector, and the orbiter is in Earth shadow.

The instrument (see Fig. 3) consists of five major components: (1) folding mirror and entrance window; (2) objective lens; (3) main spectrograph assembly; (4) detector assembly (image intensifier and film transport); and (5) electronics and power subsystem. All but item (1) are housed in a sealed Get Away Special (GAS) canister, filled with dry nitrogen at 1 atmosphere pressure. Item (1) is mounted on the top surface of the GAS canister lid.

The folding mirror and objective lens form an image of the scene to be observed on the entrance slit of the spectrograph. This provides the instrument with "imaging spectrographic" capability, i.e. the spectral distribution of intensity is displayed in one dimension (the direction perpendicular to the spectrograph slit) and the spatial distribution of intensity (along the spectrograph slit) is displayed in the transverse dimension.

The main spectrograph module consists of the entrance slit, collimating mirror, folding mirror, plane diffraction grating, and Schmidt camera. The Schmidt optics include a fused silica corrector plate, a spherical mirror, and a fused silica field-flattening lens which is placed just in front of the image intensifier faceplate (the latter is located at the prime focus of the Schmidt optical system). This assembly produces an image of the spectrum at the focal surface of the Schmidt camera. Since the 25 mm diameter format of the image intensifier can only accommodate a spectral range of 50 nm in a single exposure, four separate exposure sequences are required (with different rotation settings of the plane diffraction grating) to cover the entire 190-400 nm range.

The detector assembly consists of a proximity-focused microchannel image intensifier and film transport. The image intensifier (made by Varo, Inc.) consists of a UV-transmitting window, UV/visible sensitive photocathode, microchannel plate, phosphor screen, and fiber optic output faceplate. Photoelectrons from the photocathode are proximity focused onto the front surface of the microchannel plate (MCP), where they are multiplied by a factor of several hundred (by secondary emission multiplication in the MCP channels). These electrons are then incident on a phosphor screen which emits visible light under electron bombardment. This phosphor screen is deposited on a fiber optic plate which conducts this light to its output face, where it can be recorded on film or coupled to an electronic imaging device such as a CCD. The film transport contains 35 mm roll film (Kodak T-Max P3200) which records the image produced by the image intensifier. The film is pressed into contact with the rear fiber optic window of the intensifier during exposures. The film transport has a capacity of 15 ft. of film, sufficient for about 60 exposures.

The electronics module (see Fig. 4) contains a microprocessor sequencer and relays to operate the spectrograph film transport and grating rotation drive, in accordance with pre-programmed exposure sequences (initiated by GCD relay

command). It is planned to take a sequence of three exposures, having durations of 12, 60, and 300 seconds (375 seconds total, including film advances), at each grating rotation setting. At the end of the sequence, the grating is returned to its starting position and the microprocessor is reset. The electronics box also provides high voltage power to the image intensifier.

The HRS GS-B experiment is classified as a Complex Autonomous Payload (CAP), because several of its special requirements (such as those on orbiter attitude and time of operation) are beyond the standard services available to Get Away Special customers. However, the hardware required for the investigation is compatible with a standard GAS canister as its housing.

## CONCLUSIONS

The HRS GS-B instrument has been designed to provide moderately high spectral resolution measurements of shuttle surface glow in the 180-400 nm ultraviolet wavelength range, a hitherto little-explored spectral region. Detection and identification of the emission features responsible for the glow will allow identification of the participating chemical species and reactions. These identifications may also aid in understanding, or predicting the nature of, shuttle surface glow in other wavelength ranges not directly observed in this experiment. The HRS GS-B instrument provides a simple, low-cost means for obtaining the necessary observational data.

In addition to the author, several students have been involved (and will be involved) in the development of the HRS GS instruments, at both college and high school levels. They have worked at NRL as cooperative education (college) students and under DoD's Science and Engineering Apprentice Program for high school students.

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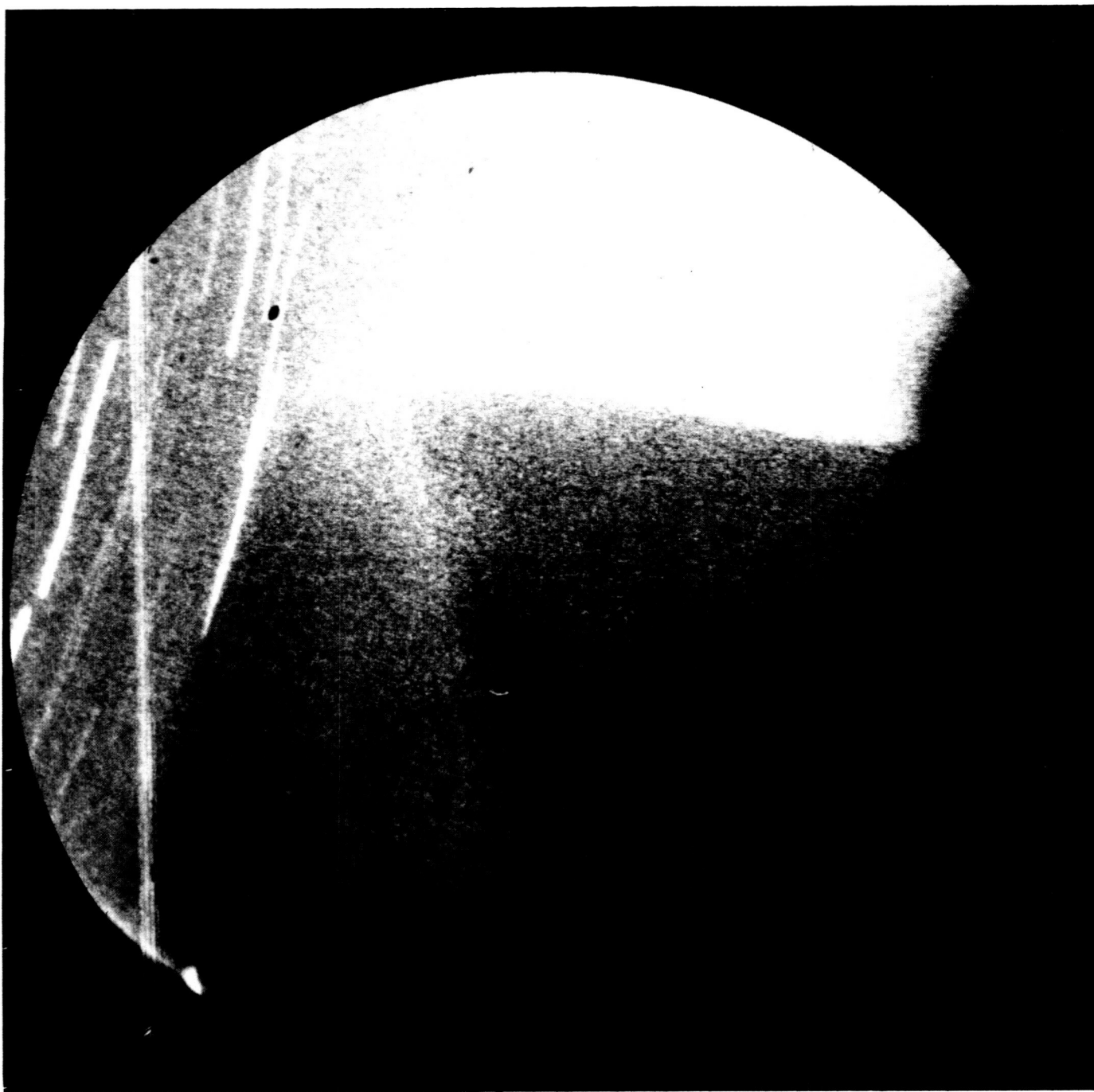


Figure 1. Far-UV (165-200 nm) image of the tail of the shuttle orbiter Discovery, obtained with the #2 Far UV Camera during the STS-39 mission (exposure time 100 seconds). Note that there is a definite "shuttle glow" in this wavelength range, and that the glow appears more diffuse (extends to a greater distance from the surface) than the corresponding visible shuttle glow.

NRL-502 HIGH RESOLUTION SHUTTLE GLOW SPECTROGRAPH  
200 - 400 nm (GAS CANISTER)

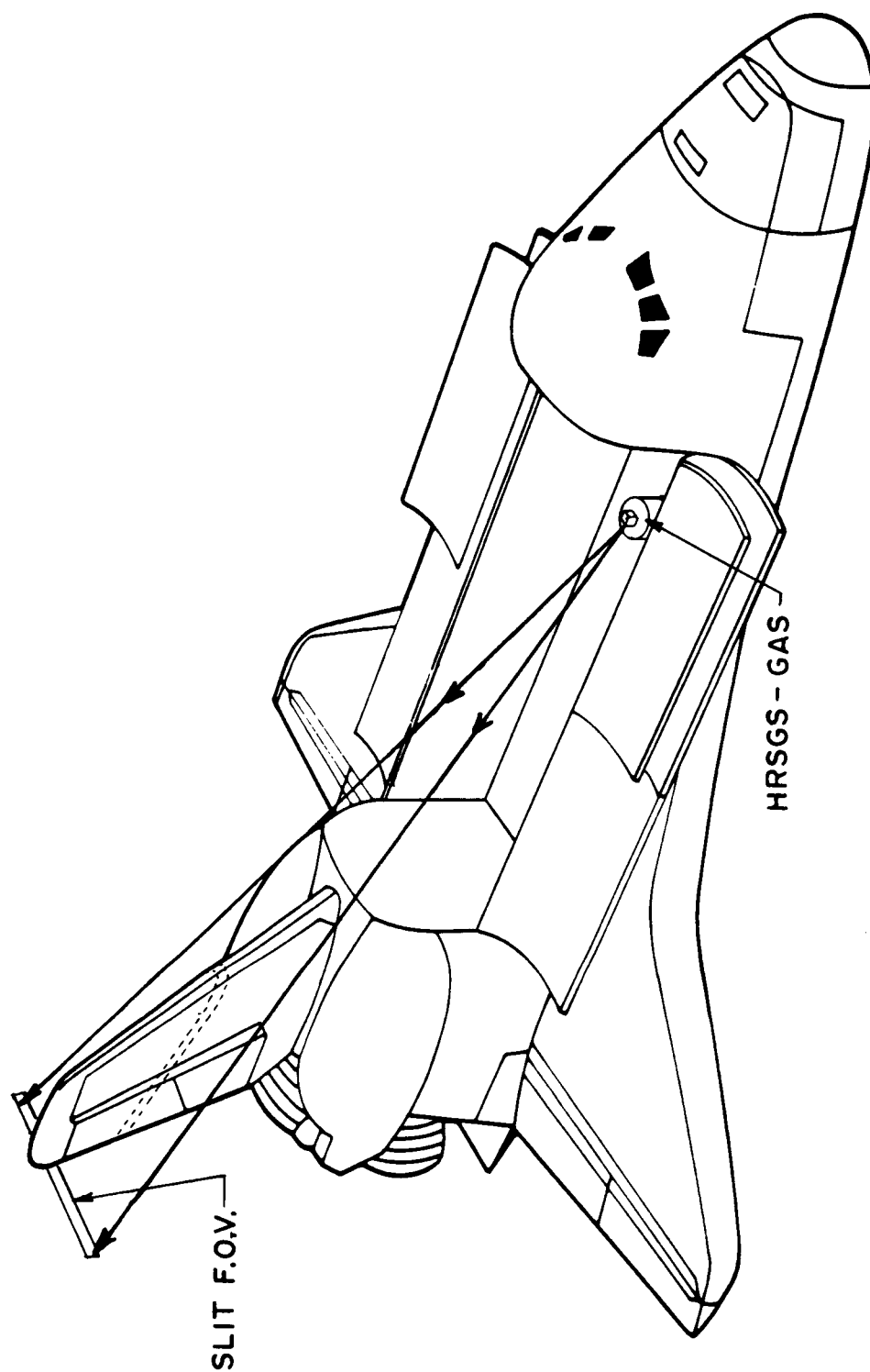
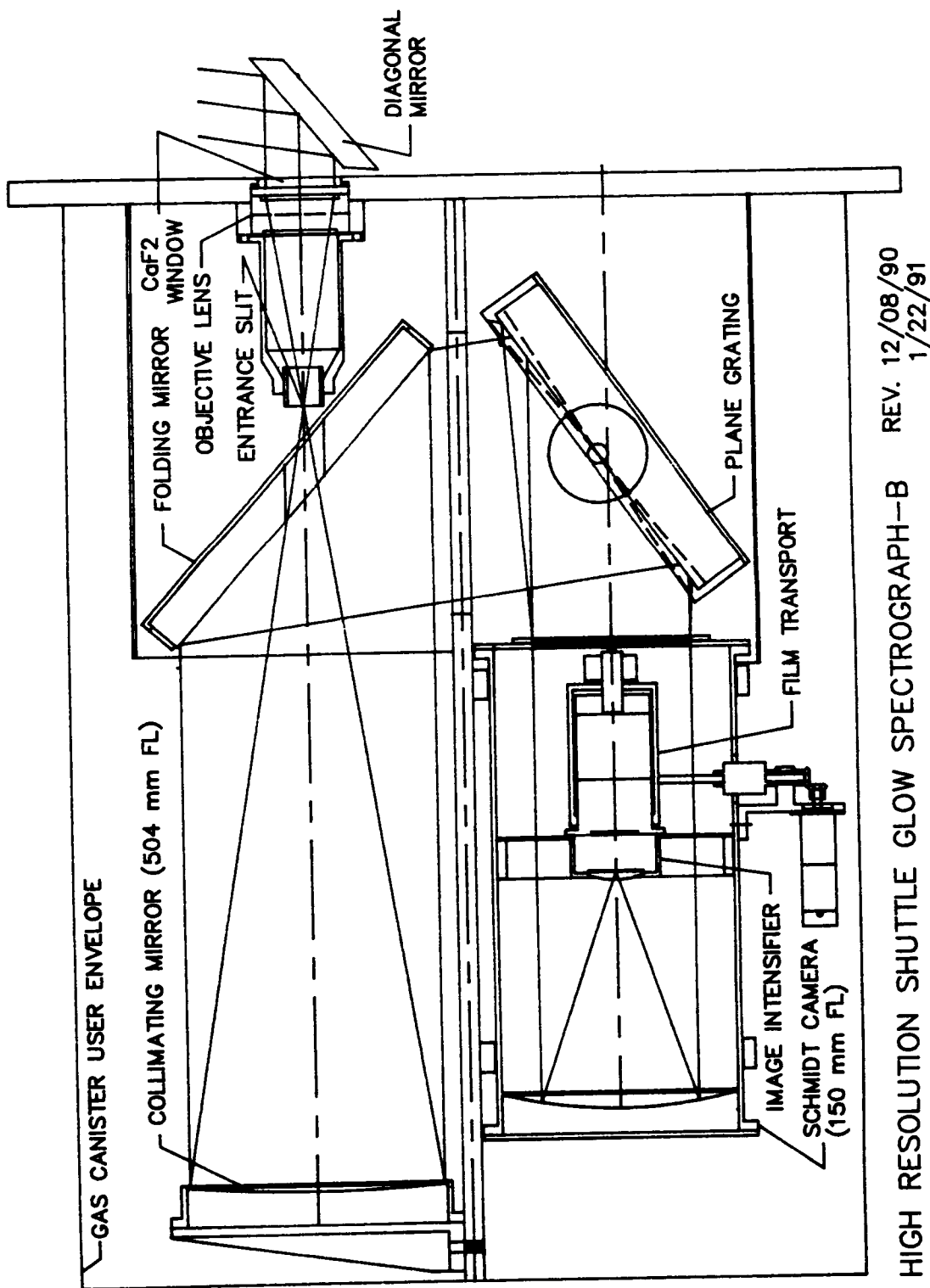


Figure 2. High Resolution Shuttle Glow Spectrograph-B (HRSGS-B) observing geometry for studies of surface glow on the orbiter vertical stabilizer and/or OMS pods.



HIGH RESOLUTION SHUTTLE GLOW SPECTROGRAPH-B REV. 12/08/90  
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Figure 3. Diagram of the HRSGS-B optical instrumentation.



# HIGH RESOLUTION SHUTTLE GLOW SPECTROGRAPH (HRSGS-B)

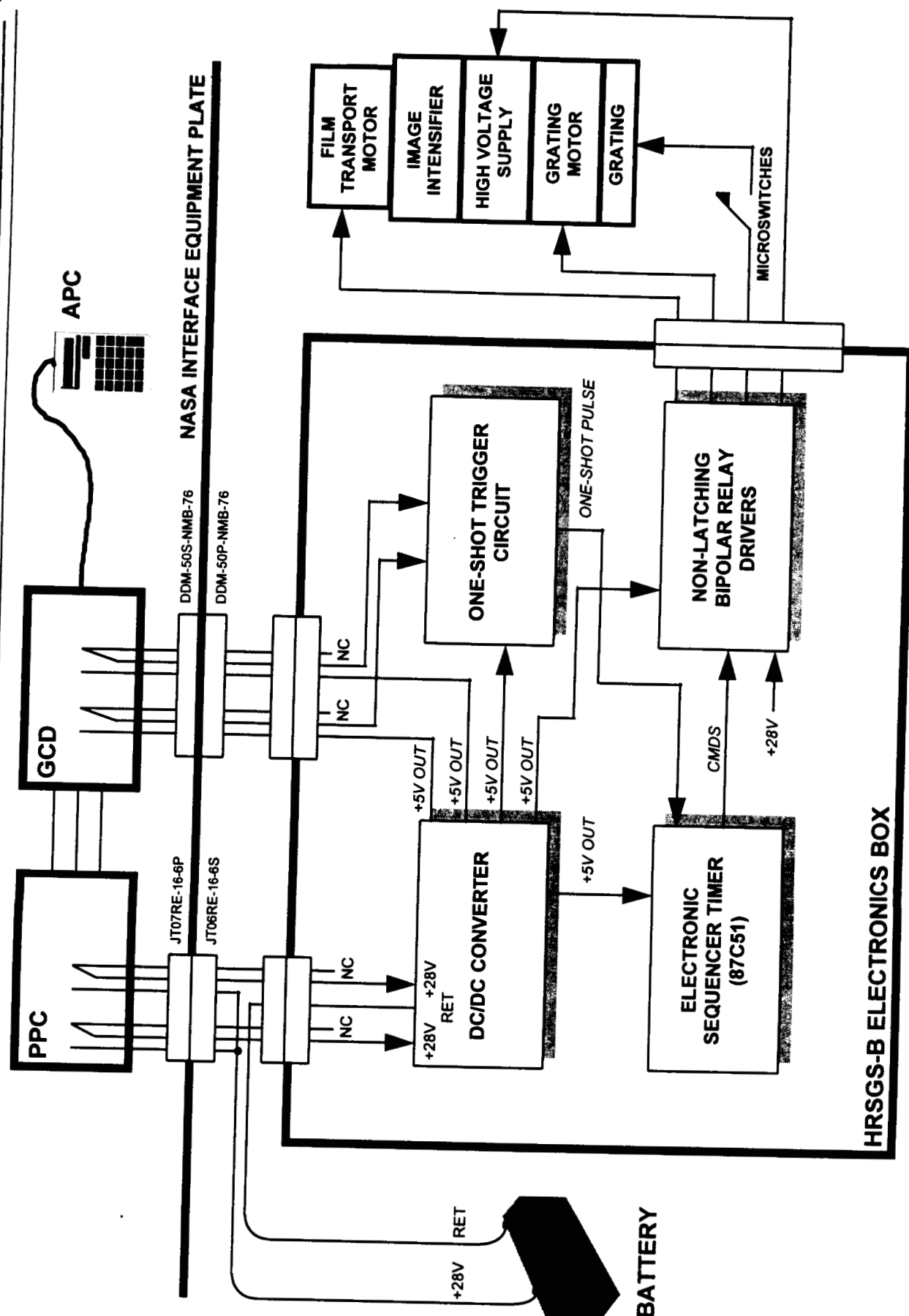


Figure 4. Block diagram of the HRSGS-B power and control electronics.